better-resourced systems, but even within dryland sorghum regions vulnerability differs sharply. In the Ethiopian studies reviewed here, Kobo emerged as more vulnerable than Miesso in part because future warming and rainfall deficits align there more strongly with yield loss. In the Great Plains of the United States, modeled stress environments differ between the northeast and southwest sorghum belt, with grain-filling water stress dominating much of the southwest. These differences matter because they also change which traits or practices are worthwhile. A trait that helps under grain-filling drought may add little benefit in a low-stress or pre-flowering-drought environment. Vulnerability, then, is not just regional climate severity. It is the frequency of the specific stress pattern that matches the crop’s sensitive stages (Carcedo et al., 2022; Gardi et al., 2025).

6.4 Future yield trends under climate scenarios

The best-supported summary of future yield trends is cautious heterogeneity. Many semi-arid sorghum systems show projected yield declines under warming, especially in rainfed and already heat-prone sites, but some environments show stable or improving simulated yields when rainfall, CO_2 fertilization, or adaptation measures offset part of the thermal stress. West African APSIM simulations earlier suggested that medium-maturing material could outperform early-maturing material under some climate scenarios, while more recent Ethiopia studies show strong site and genotype contingency. This variation should not be read as contradiction. It is evidence that future yield trends are conditional on environment, cultivar duration, and management. The practical inference is simple: climate scenarios should be used to identify likely stress profiles and adaptation niches, not to produce one global verdict on sorghum (Gardi et al., 2025; Ali and Kothari, 2026).

7 Strategies for Improving Yield Stability and Prediction Accuracy

7.1 Development of climate-resilient cultivars

The breeding literature makes clear that climate-resilient sorghum will not come from one “super trait.” Useful improvement will likely require trait combinations that align with the dominant stress pattern of target environments. These include reproductive heat tolerance, stable grain filling under water limitation, appropriate maturity duration, root-system traits, and physiological behaviors such as stay-green or limited transpiration in certain environments. Recent reviews on sorghum improvement emphasize that breeding progress will depend not only on identifying tolerant germplasm, but on linking physiological insight, quantitative genetics, and realistic target environments. Modeling can help here by testing the expected value of candidate traits before they are expensive to phenotype or introgress widely. In that sense, crop models do not replace breeding; they improve trait prioritization (Mwamahonje et al., 2024; Raymundo et al., 2024; Fontanet-Manzaneque et al., 2025).

7.2 Agronomic management practices

Agronomy remains the fastest route to stabilizing sorghum yield under climate variability because it can reposition the crop relative to stress without waiting for long breeding cycles. Sowing date is consistently important, especially in environments where early or delayed planting can help flowering avoid peak heat or terminal drought. Soil-water conservation, improved fertility, and context-appropriate irrigation also matter, but their value depends heavily on local rainfall regime and soil properties. The literature on rainwater-harvesting and deficit-irrigation modeling shows that management gains are not automatic: a practice that works in one rainfall band or soil class may fail in another. The most defensible management strategy is therefore adaptive rather than prescriptive. It should be based on dominant local stress patterns, cultivar duration, and short-term seasonal expectations (Kubiku et al., 2022; Fazel et al., 2023; Ali and Kothari, 2026).

7.3 Integration of climate information and decision support systems

A recurring gap in sorghum production is not the absence of climate data, but the weak translation of climate knowledge into field decisions. Decision-support systems can close that gap by combining weather history, seasonal outlooks, crop-model outputs, and local management rules. For sorghum, that might include sowing-window advisories, cultivar-duration matching, drought-risk maps, or irrigation scheduling. The strength of such systems is greatest when they integrate climate information with biologically meaningful crop thresholds rather than simply reporting rainfall probabilities. The broader crop-modeling literature also shows that operational systems become more valuable when they are iterative: they begin with pre-season planning, then